NASA-CR-194079

GRANT
IN-91-CR
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Final Report

for

Grant NAG 2-690

entitled

Regional Tectonic Analysis of Venus

as part of the Pioneer Venus Guest Investigator Project

Sponsored by

National Aeronautics and Space Administration

Washington, D.C.

Submitted: September 9, 1991

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Pioneer Venus Guest Investigator Project

Progress

Over the past year, much of the tectonic analysis of Venus we have done has centered on global properties of the planet, in order to understand fundamental aspects of the dynamics of the mantle and lithosphere of Venus. We have developed convection models of the Earth and Venus. These models assume whole mantle internally-heated convection. The viscosity is temperature, volatile-content, and stress dependent. An initial temperature and volatile content is assumed, and the thermal evolution is tracked for 4.6 billion years. During this time, heating occurs by decay of radiogenic elements in the mantle, and degassing and regassing of volatiles takes place at the surface. For a model assuming plate tectonics as the primary heat loss mechanism, representing the Earth through most of it's history and perhaps Venus' earlier history, degassing of the mantle was found to occur rapidly (~200 My) over a large range of parameters (Williams and Pan, 1990b, 1991b). Even for parameters chosen to represent extreme cases of an initially cool planet, low radiogenic heating, and large initial volatile complement, the mantle water content was degassed to an equilibrium value in about 2 By. These values may be applicable to the early Venus, if a large, Moon-forming impact on Earth resulted in efficient heating and loss of water (Kaula, 1990), leaving Venus with a comparably greater volatile budget and less vigorous early convection. It may therefore be impossible to retain large amounts of water in the interior of Venus until the planet cools down enough for the "cold-trap" effect to take place. This effect (Williams and Pan, 1990a) traps crust forming melts within the mantle due to a cusp in the solidus, causing these melts to refreeze at depth into a dense eclogite phase, which will inhibit ascent of this material to the surface. This effect, however, requires a hydrous mantle, so early loss of water might prevent it from taking place. Since without plate tectonics there is no mechanism for regassing volatiles into the mantle, as occurs on Earth at subduction zones, this means the interior of Venus would at present be almost completely dry. We have also calculated argon degassing, and mantle flow velocities. viscosities, and cooling rates in these models, and these values can provide constraints on present day mantle dynamics.

We have modelled Venus with an initially hydrous mantle to determine how the "cold-trap" could affect the evolution of the planet (Williams and Pan, 1991a). Assuming heat and volatiles are lost through extrusion of material onto the surface, this leads to an episodic magmatic history. During periods of no magmatism when the cold-trap is in effect, the inefficient loss of heat due to conduction alone causes the temperature

to rise. At a high enough temperature, the cold-trap no longer operates, and magma will reach the surface in large volumes. This leads, at least locally, to an efficient loss of heat and volatiles from the interior. Cooling of the interior causes the cold-trap to take effect, and the cycle begins again. This effect could take place on a regional scale. This is one possible explanation of the episodic nature of large-scale volcanism seen in the Magellan images (Phillips et al., 1991). We are planning to explore some of these cases in detail, and examine effects of our assumptions about rates of conductive cooling and loss of volatiles due to magmatism. We also plan to develop models of planetary accretion to determine constraints on the initial volatile and heat budgets of the Earth and Venus.

One important parameter needed to understand the effects of stress on surface morphology is the crustal thickness. We have attempted to put constraints on this value through the use of crustal extrusion models (Bird and Williams, 1990). For a given crustal thickness, surface features of different wavelengths will relax at different rates due to the extrusion of hotter crustal material from beneath the feature (Bird, 1991). Two-dimensional Fourier analysis was used to determine the power spectra of the Venus topography for different areas in the equatorial highlands. These spectra showed that no significant wavelength-dependent relaxation has taken place in these areas. Given the high Venus surface temperature, this limits the crustal thickness for reasonable values of heat flow to less than 20 km in the highland regions studied, unless these regions are very young and have not had time to relax. We plan to extend this study, and also to use a more detailed data set to examine these features.

Finally, we have been studying the effects of thermal plumes on erosion and uplift of the lithosphere (Fishbein, 1988). Thermal erosion of the lithosphere and tractions exerted at the base of the lithosphere result in stresses at the surface. These stresses can be calculated for various plume models, and compared with the surface morphology of candidate hot-spot areas in the equatorial highlands. This work is currently in progress, and should yield results which will be useful in determining whether plumes are responsible for much of the equatorial highland topography and the nature and size of these plumes.

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